

Supplementary Information

Article Title: Genetic loci underlying important shoot morphological traits of wild emmer wheat revealed by GWAS

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Supplementary tables

Supplementary Table 1: List of 263 wild emmer accessions studied in this experiment, along with their collection location and population.

SL no	Genotypes	Collection location	Population
1	TD8	Qazrin	Central, Israel
2	TD9	Qazrin	Central, Israel
3	TD10	Qazrin	Central, Israel
4	TD12	Yehudiyya	Central, Israel
5	TD13	Yehudiyya	Central, Israel
6	TD14	Yehudiyya	Central, Israel
7	TD16	Yehudiyya	Central, Israel
8	TD18	Yehudiyya	Central, Israel
9	TD19	Yehudiyya	Central, Israel
10	TD20	Yehudiyya	Central, Israel
11	TD21	Yehudiyya-Shady	Central, Israel
12	TD22	Yehudiyya-Shady	Central, Israel
13	TD23	Yehudiyya-Shady	Central, Israel
14	TD24	Yehudiyya-Shady	Central, Israel
15	TD25	Yehudiyya-Shady	Central, Israel
16	TD26	Yehudiyya-Shady	Central, Israel
17	TD28	Yehudiyya-Shady	Central, Israel
18	TD30	Yehudiyya-Shady	Central, Israel

19	TD33	Yehudiyya-Shady	Central, Israel
20	TD34	Yehudiyya-Shady	Central, Israel
21	TD35	Yehudiyya-Shady	Central, Israel
22	TD37	Yehudiyya-Shady	Central, Israel
23	TD38	Yehudiyya-Shady	Central, Israel
24	TD39	Yehudiyya-Shady	Central, Israel
25	TD40	Yehudiyya-Shady	Central, Israel
26	TD41	Yehudiyya-Shady	Central, Israel
27	TD42	Yehudiyya-Shady	Central, Israel
28	TD43	Yehudiyya-Shady	Central, Israel
29	TD44	Yehudiyya-Shady	Central, Israel
30	TD45	Yehudiyya-Shady	Central, Israel
31	TD46	Yehudiyya-Shady	Central, Israel
32	TD47	Yehudiyya-Shady	Central, Israel
33	TD48	Yehudiyya-Shady	Central, Israel
34	TD49	Yehudiyya-Shady	Central, Israel
35	TD50	Yehudiyya-Shady	Central, Israel
36	TD51	Yehudiyya-Shady	Central, Israel
37	TD52	Yehudiyya-Shady	Central, Israel
38	TD53	Yehudiyya-Shady	Central, Israel
39	TD54	Yehudiyya-Shady	Central, Israel
40	TD55	Yehudiyya-Shady	Central, Israel
41	TD56	Yehudiyya-Shady	Central, Israel
42	TD57	Yehudiyya-Shady	Central, Israel
43	TD58	Yehudiyya-Shady	Central, Israel
44	TD60	Yehudiyya-Shady	Central, Israel
45	TD61	Yehudiyya-Shady	Central, Israel
46	TD62	Yehudiyya-Shady	Central, Israel
47	TD64	Yehudiyya-Shady	Central, Israel
48	TD65	Yehudiyya-Shady	Central, Israel
49	TD66	Yehudiyya-Shady	Central, Israel
50	TD69	Yehudiyya-Shady	Central, Israel
51	TD70	Yehudiyya-Shady	Central, Israel
52	TD71	Yehudiyya-Shady	Central, Israel
53	TD72	Yehudiyya-Shady	Central, Israel
54	TD73	Yehudiyya-Shady	Central, Israel
55	TD74	Yehudiyya-Sun	Central, Israel
56	TD75	Yehudiyya-Sun	Central, Israel
57	TD78	Yehudiyya-Sun	Central, Israel
58	TD79	Yehudiyya-Sun	Central, Israel
59	TD81	Yehudiyya-Sun	Central, Israel
60	TD82	Yehudiyya-Sun	Central, Israel
61	TD84	Yehudiyya-Sun	Central, Israel
62	TD87	Yehudiyya-Sun	Central, Israel
63	TD89	Yehudiyya-Sun	Central, Israel

64	TD90	Yehudiyya-Sun	Central, Israel
65	TD94	Yehudiyya-Sun	Central, Israel
66	TD95	Yehudiyya-Sun	Central, Israel
67	TD96	Yehudiyya-Sun	Central, Israel
68	TD98	Yehudiyya-Sun	Central, Israel
69	TD101	Yehudiyya-Sun	Central, Israel
70	TD101	Yehudiyya-Sun	Central, Israel
71	TD108	Yehudiyya-Sun	Central, Israel
72	TD110	Yehudiyya-Sun	Central, Israel
73	TD112	Yehudiyya-Sun	Central, Israel
74	TD118	Yehudiyya-Sun	Central, Israel
75	TD120	Yehudiyya-Sun	Central, Israel
76	TD121	Yehudiyya-Sun	Central, Israel
77	TD123	Yehudiyya-Sun	Central, Israel
78	TD124	Yehudiyya-Sun	Central, Israel
79	TD125	Yehudiyya-Sun	Central, Israel
80	TD126	Yehudiyya-Sun	Central, Israel
81	TD130	Gamla	Central, Israel
82	TD135	Gamla	Central, Israel
83	TD136	Gamla	Central, Israel
84	TD137	Gamla	Central, Israel
85	TD139	Rosh-Pinna	Central, Israel
86	TD140	Rosh-Pinna	Central, Israel
87	TD141	Rosh-Pinna	Central, Israel
88	TD142	Rosh-Pinna	Central, Israel
89	TD148	Ammiad-85	Admixed, Israel
90	TD159	Tabigha 1979	Central, Israel
91	TD161	Tabigha 1979	Central, Israel
92	TD164	Tabigha 1979	Central, Israel
93	TD165	Tabigha 1979	Central, Israel
94	TD166	Tabigha 1979	Central, Israel
95	TD167	Tabigha 1979	Central, Israel
96	TD169	Tabigha-Basalt	Central, Israel
97	TD181	Tabigha-Terra	Central, Israel
98	TD182	Tabigha-Terra	Central, Israel
99	TD195	Mt. Gilboa	South, Israel
100	TD202	Mt. Gerizim	South, Israel
101	TD203	Mt. Gerizim	South, Israel
102	TD204	Mt. Gerizim	South, Israel
103	TD205	Mt. Gerizim	South, Israel
104	TD206	Mt. Gerizim	South, Israel
105	TD211	Gitit	South, Israel
106	TD216	Gitit	South, Israel
107	TD220	Kokhav-Hashahar	South, Israel
108	TD230	Taiyiba	South, Israel

109	TD246	Sanhedriyya	South, Israel
110	TD247	Sanhedriyya	South, Israel
111	TD252	Bet-Meir	South, Israel
112	TD256	Bet-Meir	South, Israel
113	TD260	J'aba	South, Israel
114	TD263	J'aba	South, Israel
115	TD265	J'aba	South, Israel
116	TD268	Amirim	West, Israel
117	TD272	Amirim	West, Israel
118	TD292	Nesher	West, Israel
119	TD301	Beit-Oren	West, Israel
120	TD304	Beit-Oren	West, Israel
121	TD305	Beit-Oren	West, Israel
122	TD310	Daliyya	West, Israel
123	TD314	Daliyya	West, Israel
124	TD316	Daliyya	West, Israel
125	TD317	Bat-Shelomo	West, Israel
126	TD326	Bat-Shelomo	West, Israel
127	TD330	Kabara	Admixed, Israel
128	TD333	Kabara	Admixed, Israel
129	TD380	N Diyarbakir	Turkey
130	TD382	N Diyarbakir	Turkey
131	TD383	N Diyarbakir	Turkey
132	TD385	N Diyarbakir	Turkey
133	TD386	N Diyarbakir	Turkey
134	TD392	Mt. Hermon	North, Israel
135	TD393	Mt. Hermon	North, Israel
136	TD398	-	Admixed, Israel
137	TD403	-	Admixed, Israel
138	TD405	-	Admixed, Israel
139	TD407	-	Admixed, Israel
140	TD409	-	Admixed, Israel
141	TD410	-	Admixed, Israel
142	TD412	-	Admixed, Israel
143	TD413	-	Admixed, Israel
144	TD415	-	Admixed, Israel
145	TD416	-	Admixed, Israel
146	TD417	-	Admixed, Israel
147	TD418	-	Admixed, Israel
148	TD419	-	Admixed, Israel
149	TD420	-	Admixed, Israel
150	TD421	-	Admixed, Israel
151	TD422	-	Admixed, Israel
152	TD425	-	Admixed, Israel
153	TD427	-	Admixed, Israel

154	TD429	-	Admixed, Israel
155	TD430	-	Admixed, Israel
156	TD436	-	Admixed, Israel
157	TD440	-	Admixed, Israel
158	TD450	-	Admixed, Israel
159	TD453	-	Lebanon
160	TD454	-	Lebanon
161	TD459	-	Admixed, Israel
162	TD460	-	Admixed, Israel
163	TD463	-	Admixed, Israel
164	TD464	-	Iran
165	TD511	-	Turkey
166	TD513	-	Admixed, Israel
167	TD517	-	Lebanon
168	TD518	-	Lebanon
169	TD522	-	Lebanon
170	TD525	-	Lebanon
171	TD526	-	Lebanon
172	TD528	-	Lebanon
173	TD529	-	Lebanon
174	TD532	-	Lebanon
175	TD533	-	Turkey
176	TD534	-	Turkey
177	TD535	-	Turkey
178	TD537	-	Syria
179	TD538	-	Syria
180	TD540	-	Syria
181	TD543	-	Syria
182	TD544	-	Syria
183	TD545	-	Syria
184	TD546	-	Syria
185	TD550	-	Syria
186	TD554	-	Admixed, Israel
187	TD570	-	Syria
188	TD571	-	Syria
189	TD572	-	Syria
190	TD574	-	Syria
191	TD575	-	Syria
192	TD576	-	Syria
193	TD577	-	Syria
194	TD580	-	Syria
195	TD591	-	Lebanon
196	TD592	-	Lebanon
197	TD639	-	Syria
198	TD640	-	Syria

199	TD646	-	Syria
200	TD651	-	Lebanon
201	TD694	-	Turkey
202	TD721	-	Lebanon
203	TD722	-	Lebanon
204	TD728	-	Lebanon
205	TD734	-	Turkey
206	TD741	-	Turkey
207	TD743	-	Turkey
208	TD745	-	Turkey
209	TD761	-	Admixed, Israel
210	TD764	-	Admixed, Israel
211	TD766	-	Admixed, Israel
212	TD767	-	Admixed, Israel
213	TD768	-	Admixed, Israel
214	TD770	-	Admixed, Israel
215	TD771	-	Admixed, Israel
216	TD772	-	Admixed, Israel
217	TD773	-	Admixed, Israel
218	TD774	-	Admixed, Israel
219	TRTD03	Tabigha, Terra rossa,	Central, Israel
220	TRTD04	Tabigha, Terra rossa,	Central, Israel
221	TRTD06	Tabigha, Terra rossa,	Central, Israel
222	TRTD07	Tabigha, Terra rossa,	Central, Israel
223	TRTD08	Tabigha, Terra rossa,	Central, Israel
224	TRTD09	Tabigha, Terra rossa,	Central, Israel
225	TRTD10	Tabigha, Terra rossa,	Central, Israel
226	TRTD11	Tabigha, Terra rossa,	Central, Israel
227	TRTD12	Tabigha, Terra rossa,	Central, Israel
228	TRTD13	Tabigha, Basalt	Central, Israel
229	TRTD14	Tabigha, Basalt	Central, Israel
230	TRTD15	Tabigha, Basalt	Central, Israel
231	TRTD16	Tabigha, Basalt	Central, Israel
232	TRTD17	Tabigha, Basalt	Central, Israel
233	TRTD19	Tabigha, Basalt	Central, Israel
234	TRTD20	Tabigha, Basalt	Central, Israel
235	TRTD21	Tabigha, Basalt	Central, Israel
236	TRTD22	Tabigha, Basalt	Central, Israel
237	TRTD24	Tabigha, Basalt	Central, Israel
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239	TRTD26	Tabigha, Basalt	Central, Israel
240	TRTD27	Tabigha, Basalt	Central, Israel
241	TRTD29	Tabigha, Basalt	Central, Israel
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243	TRTD31	Tabigha, Basalt	Central, Israel

244	TRTD32	Tabigha, Basalt	Central, Israel
245	TRTD36	Tabigha, Basalt	Central, Israel
246	TRTD37	Tabigha, Basalt	Central, Israel
247	TRTD38	Tabigha, Basalt	Central, Israel
248	TRTD39	Tabigha, Basalt	Central, Israel
249	TRTD40	Tabigha, Basalt	Central, Israel
250	TRTD41	Tabigha, Basalt	Central, Israel
251	TRTD42	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
252	TRTD43	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
253	TRTD45	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
254	TRTD51	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
255	TRTD53	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
256	TRTD54	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
257	TRTD57	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
258	TRTD60	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
259	TRTD61	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
260	TRTD64	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
261	TRTD65	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
262	TRTD66	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel
263	TRTD69	Evolution Canyon 1 (EC1)	Evolution Canyon 1, Israel

Supplementary table 1: Lists of 19 shoot morphological traits with the procedure followed for recording data.

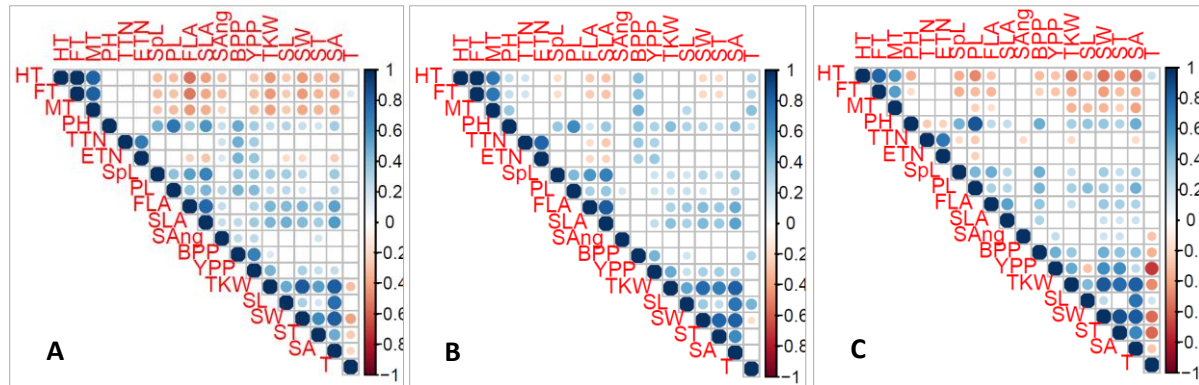
Traits	Abbreviations	Unit	Descriptions
Heading time	HT	Days	Data were recorded when spike comes out from flag leaf sheath in at least 50% of the plants for each accession.
Flowering time	FT	Days	When 50% of the plant for each accession started to flower (another comes out from spikelet).
Maturity time	MT	Days	The time when 50% of total plants turn into physiological maturity (dry peduncle and awns).
Plant height	PH	cm	Length between plant base and spike top (without awn) of the main tiller.
Total tiller number	TTN		All tillers were counted.
Effective tiller number	ETN		Only tillers with spikes were counted.
Spike length	SpL	cm	Length between base and spike top (without awn) of the main tiller.

Peduncle length	PL	cm	Length between the topmost node and spike top (without awn) of the main tiller.
Flag leaf area	FLA	cm ²	Leaf area was calculated using the formula: Leaf area = Length X breath X 0.75
Second leaf area	SLA	cm ²	
Yield/plant	YPP	g	Average seed weight of all plants for each accession after threshing.
Biomass/plant	BPP	g	Average of the whole plant (including spike) for each accession after oven drying.
Shoot angle	Sang	degree	Protractor was used to measure angles between effective tillers and soil surface (Average value was considered), range of angles was 0° to 90°.
Thousand kernel weight	TKW	g	Seeds were scanned using a SeedCount Machine (Next Instruments Pty Ltd.), and the SeedCount Image Analyzer software generated the trait values.
Seed length	SL	mm	
Seed width	SW	mm	
Seed thickness	ST	mm	
Seed area	SA	mm ²	
Threshability	T		Threshability was scored on a 1-4 scale where 1 = completely free-threshing with virtually all seed released from the hulls; 2 = mostly free-threshing with a minor portion of the seed remaining hulled; 3 = somewhat difficult to thresh with a major portion of the seed remaining hulled; and 4 = difficult to thresh with only a few seeds being released from the hulls. The same person carried out all the threshing work to reduce scoring errors.

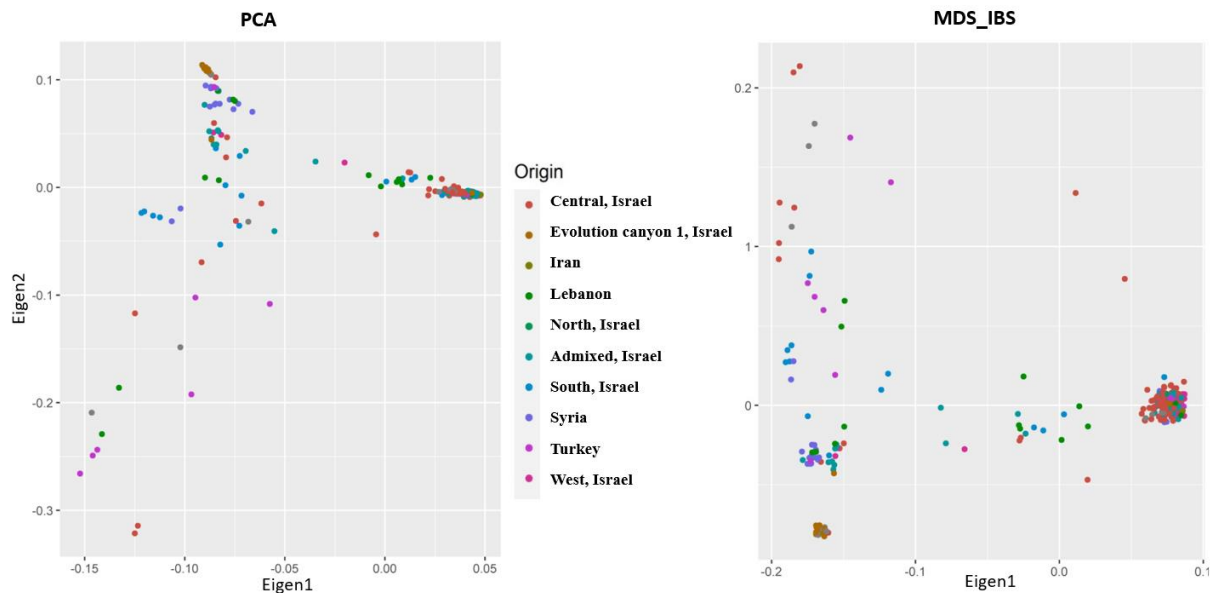
Supplementary table 3: Summary of genetic diversity and PIC values for the eight populations of wild emmer.

Population	Sample size	Mean value of genetic diversity	Mean PIC value
Central area, Israel	129	0.3161	0.2817
South area, Israel	17	0.4896	0.4257
West area, Israel	11	0.3477	0.3005
Evolutionary Canyon 1 (EC1), Israel	13	0.1954	0.1707
Admixed, Israel	41	0.3971	0.3515
Turkey	14	0.4817	0.4165
Lebanon	16	0.4802	0.4197
Syria	19	0.3547	0.3068

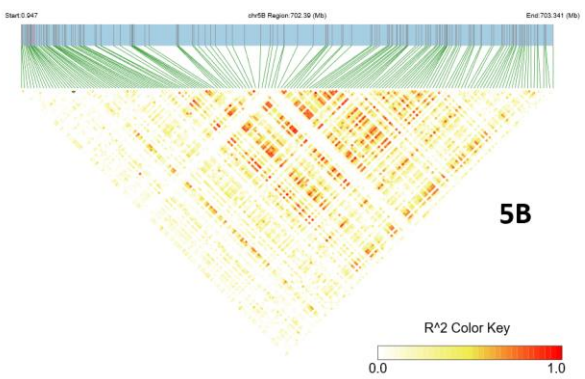
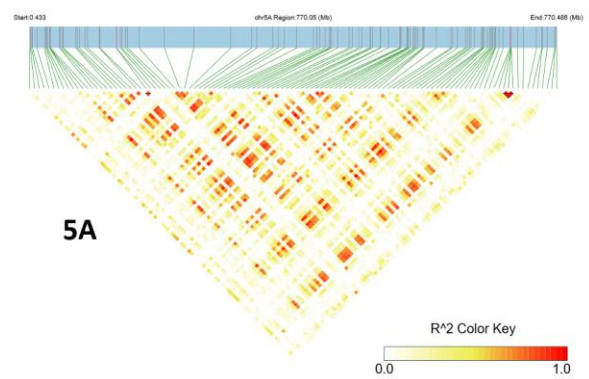
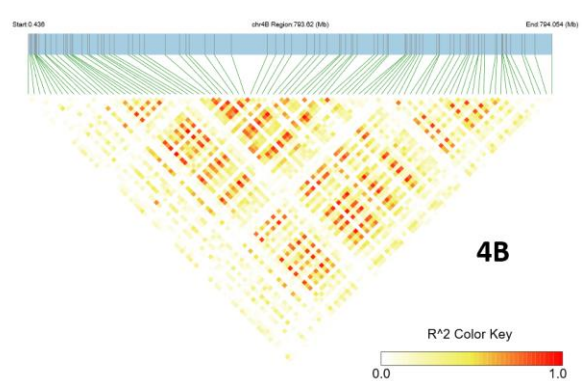
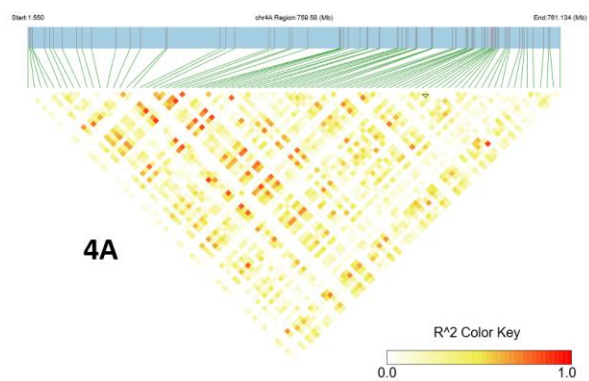
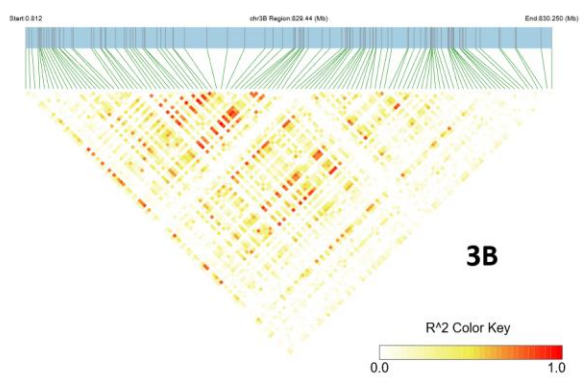
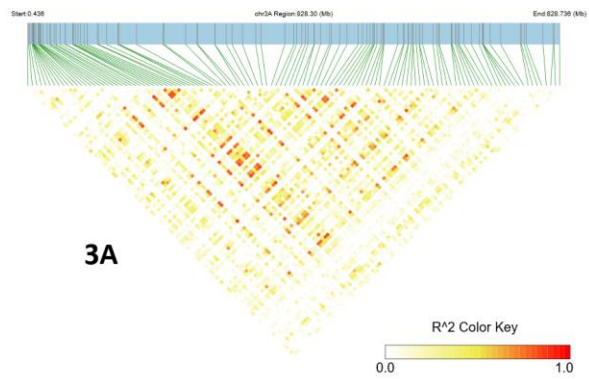
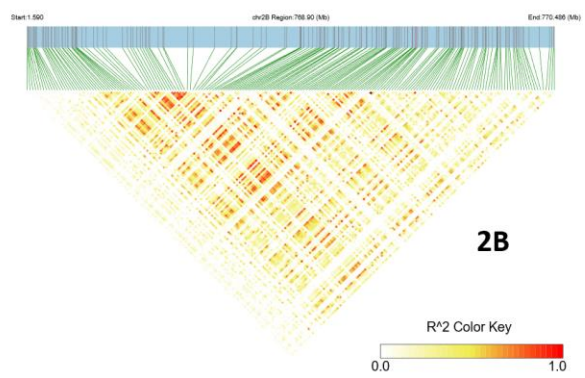
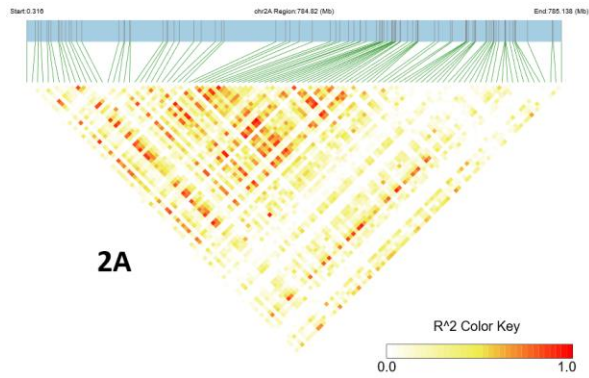
Supplementary figure

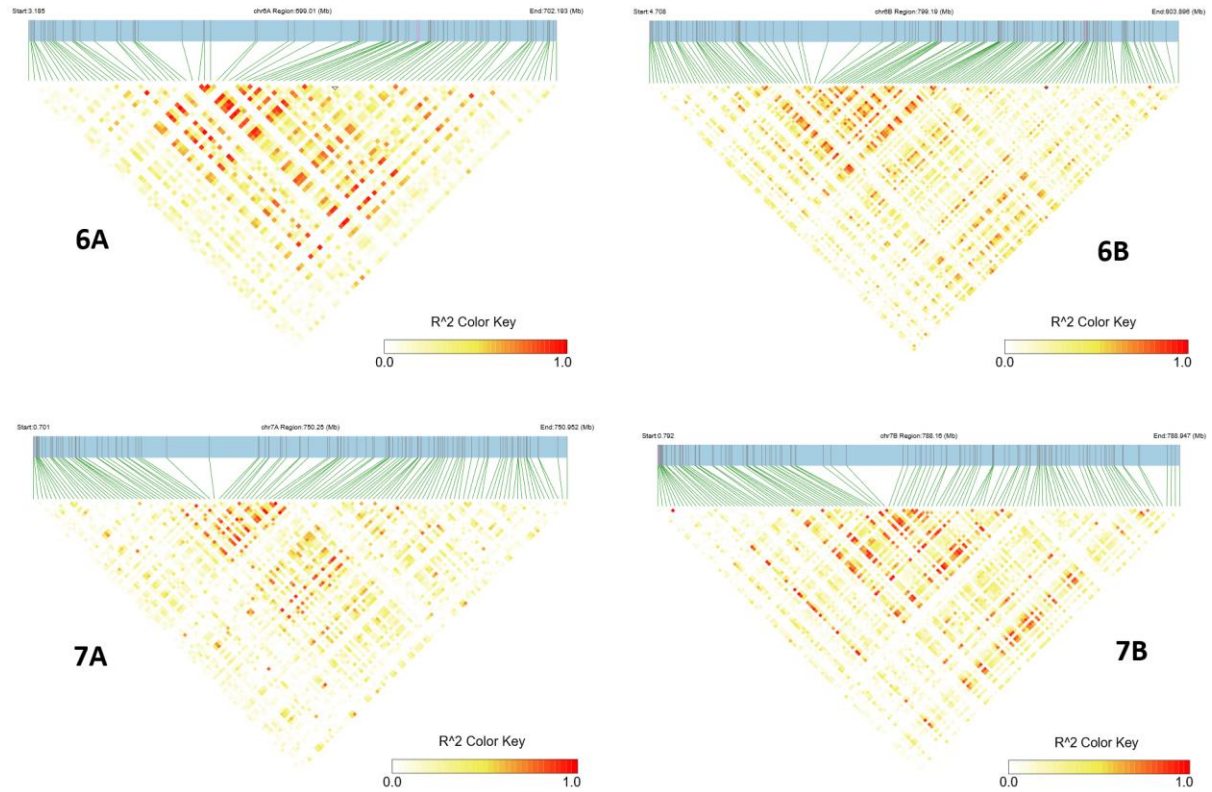


Supplementary Fig. 1: Correlation analysis between 19 above ground traits in three different environments i.e. (A) GH trial-2019, E1, (B) GH trial-2020, E2 and (C) Field trial-2020, E3. Significantly positive or negative correlations ($p < 0.01$) are displayed in blue and red, respectively, and colour intensity and circle size are proportional to the correlation coefficients. Note: HT: heading time; FT: flowering time; MT, maturity time; PH: plant height; TTN: total tiller number; ETN: effective tiller number; SpL: spike length; PL: peduncle length; FLA: flag leaf area; SLA: second leaf area; SAng: shoot angle; BPP: biomass/plant; YPP: yield/plant; TKW: thousand kernel weight; SL: seed length; SW: seed width; ST: seed thickness; SA: seed area; T: threshability.

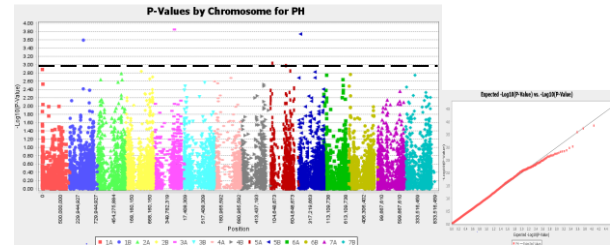
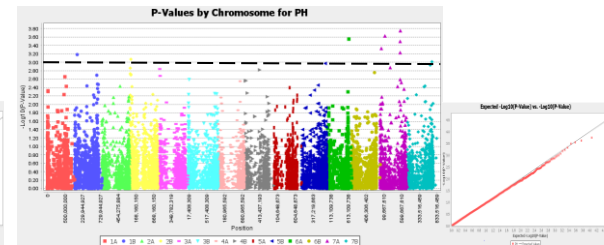
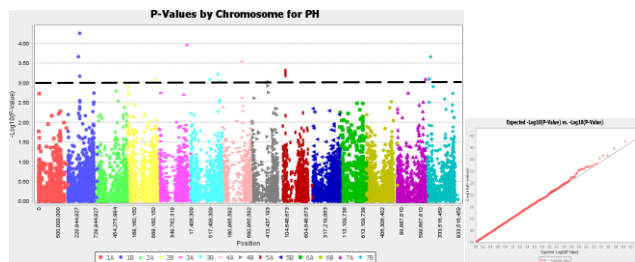
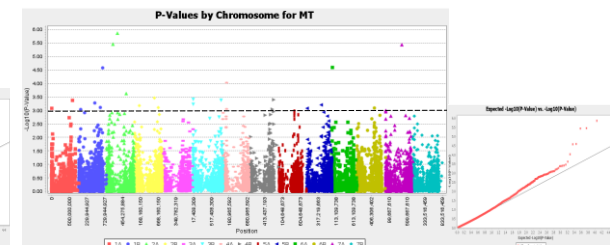
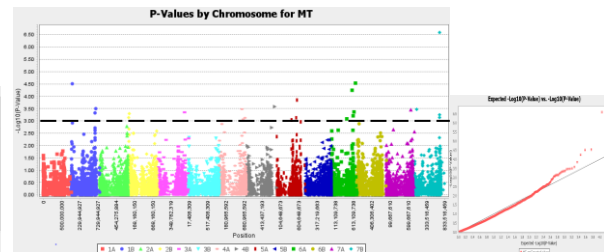
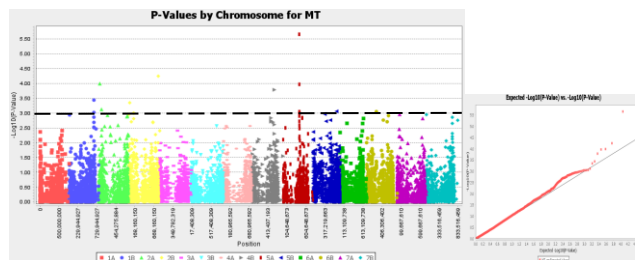
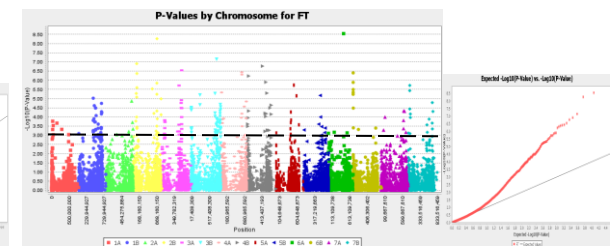
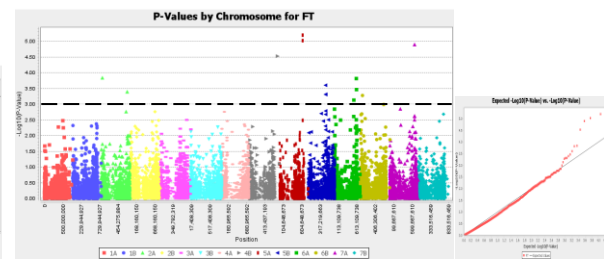
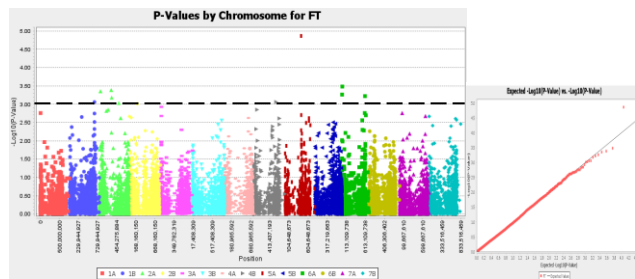
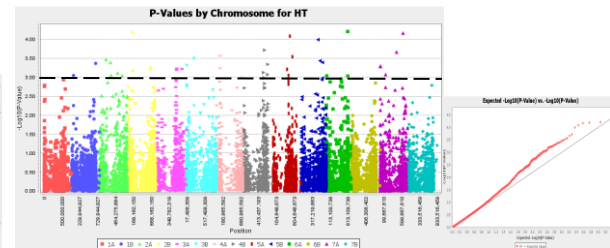
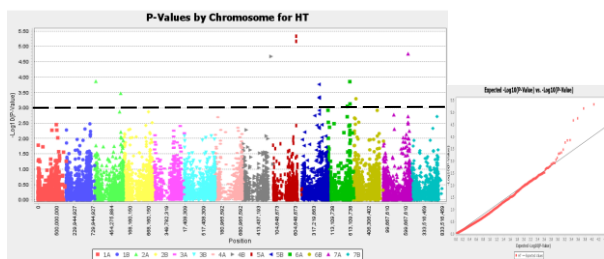
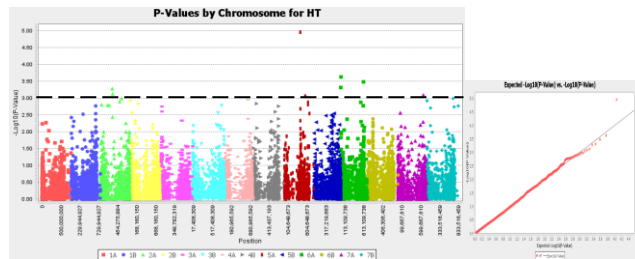


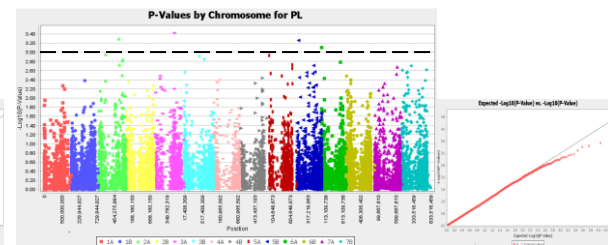
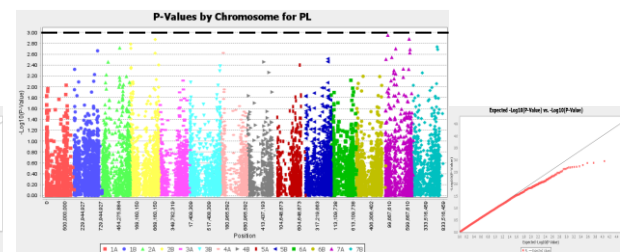
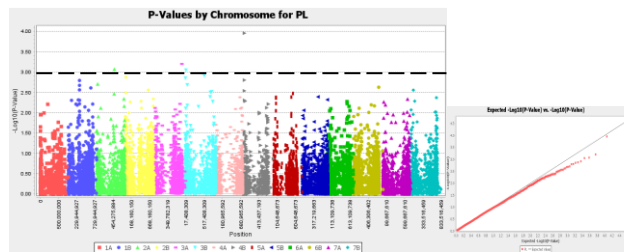
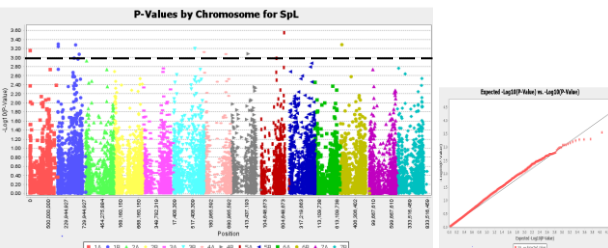
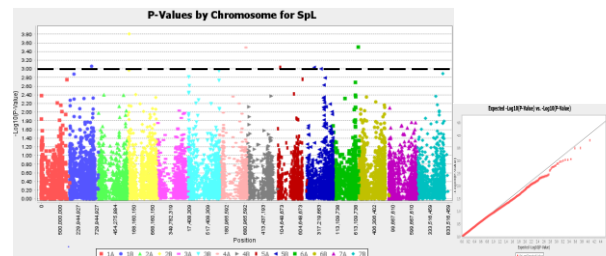
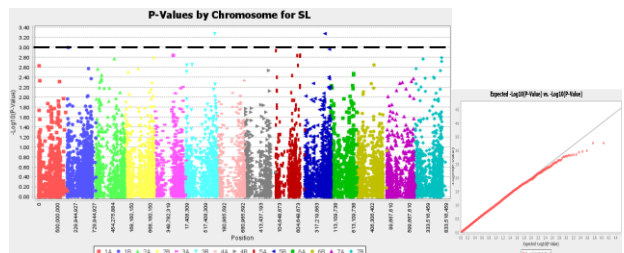
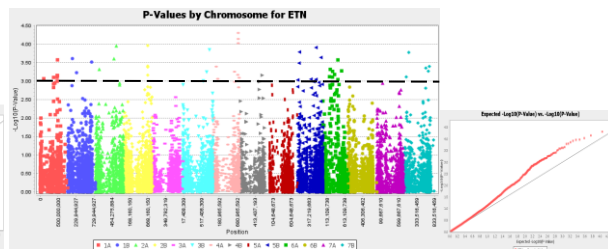
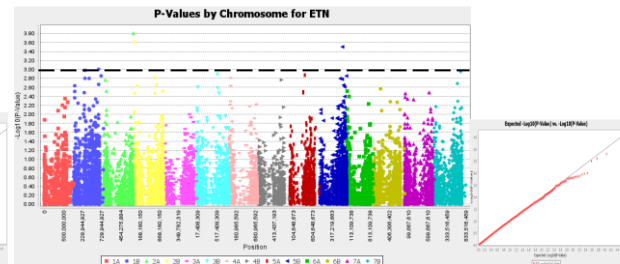
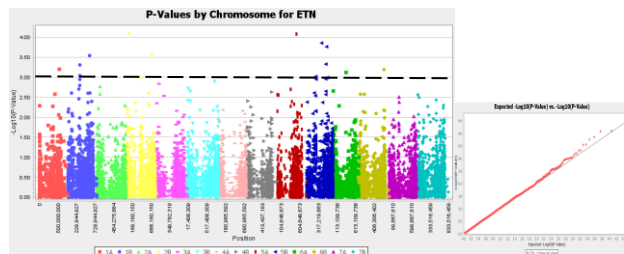
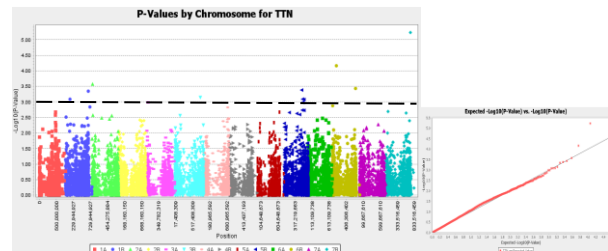
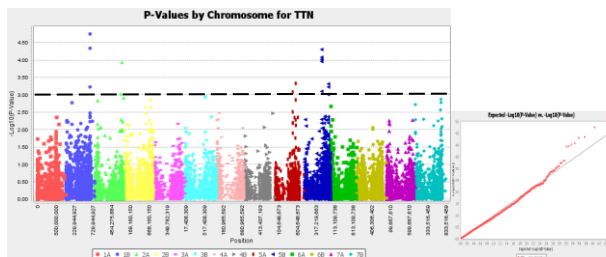
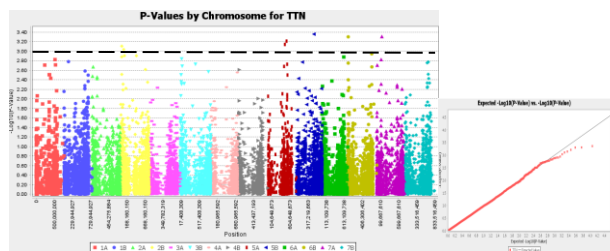
Supplementary Fig. 2: PCA and MDS plots of 263 wild emmer accessions marked with collected location/ origin.

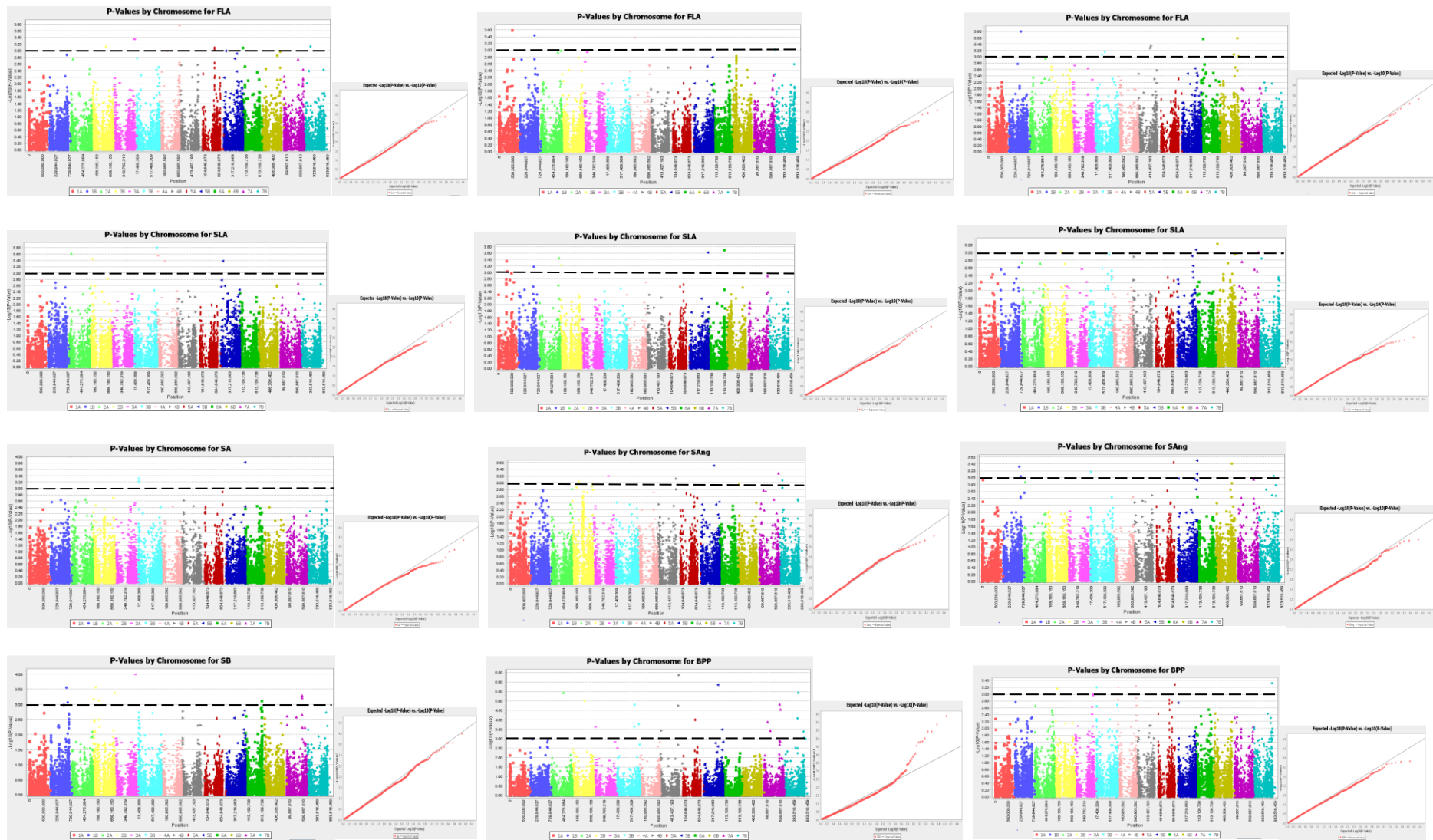


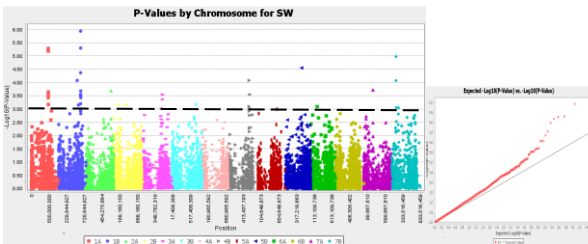
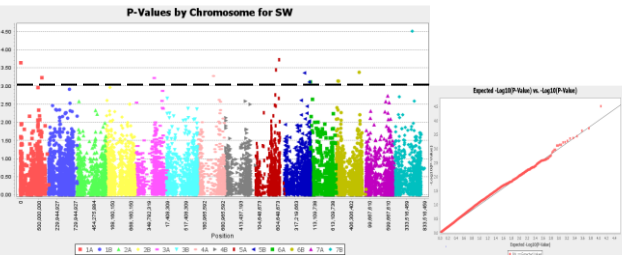
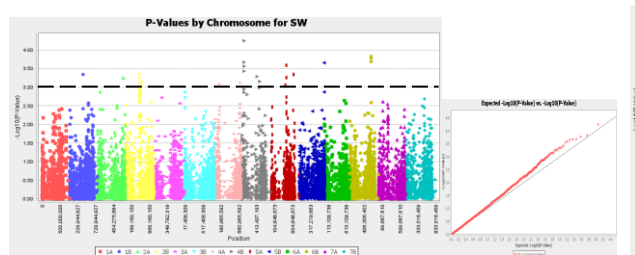
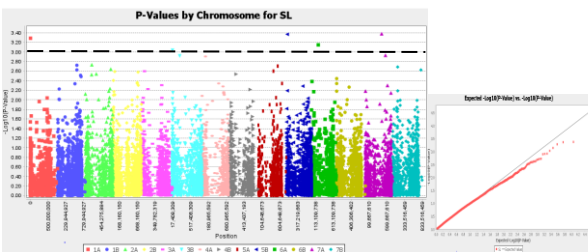
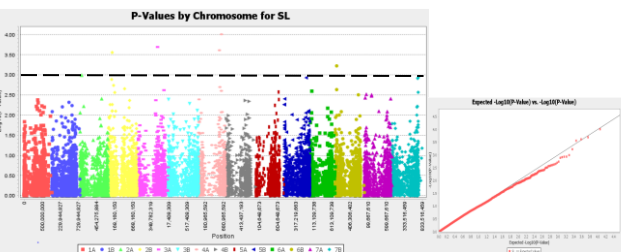
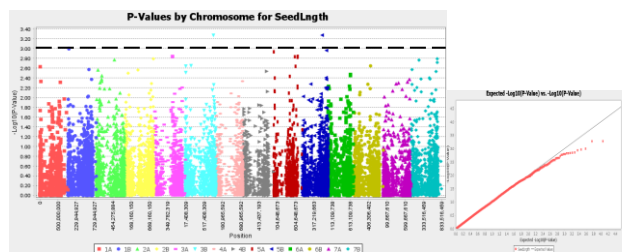
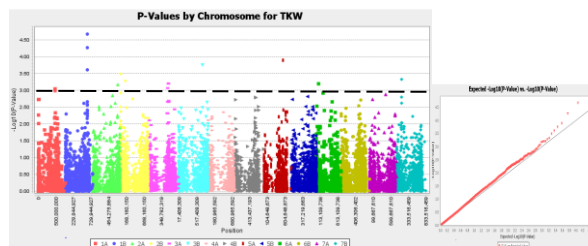
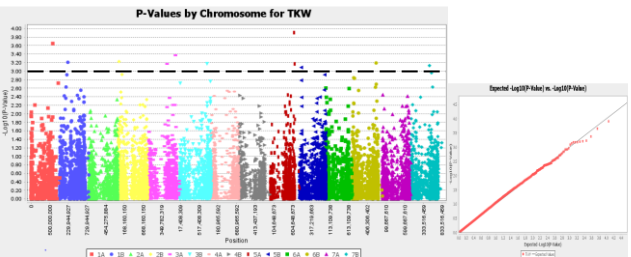
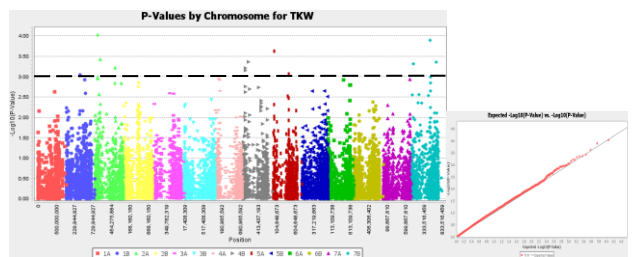
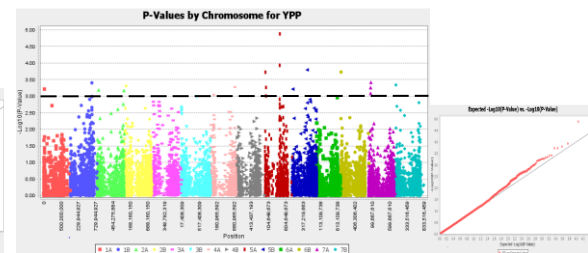
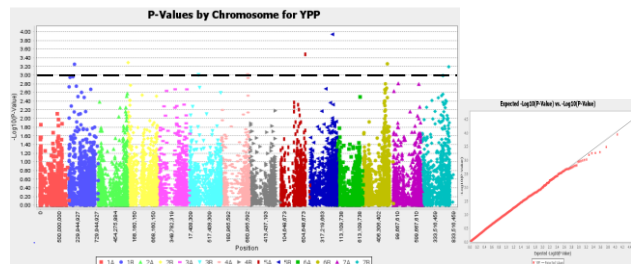
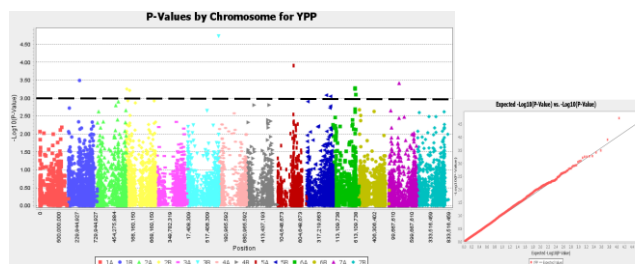


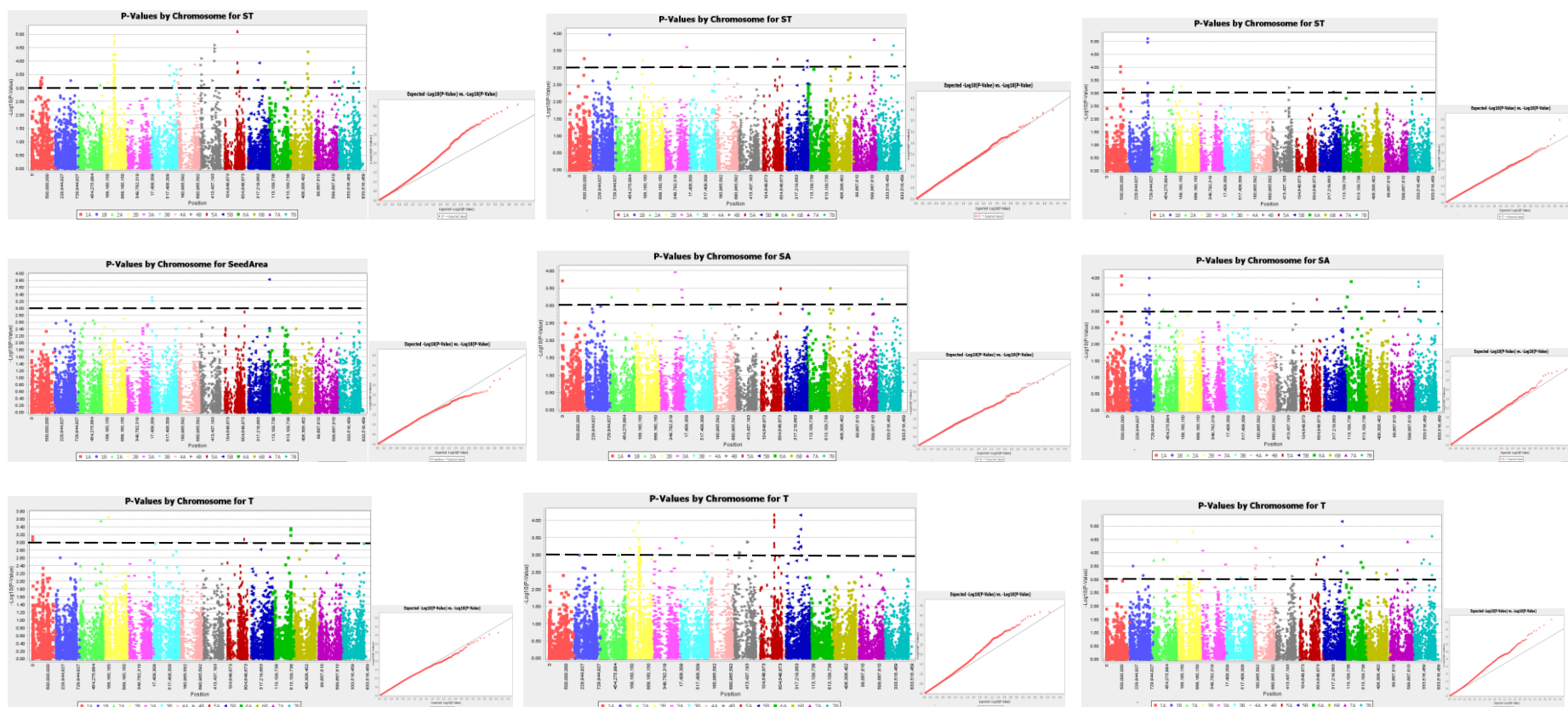
Supplementary fig. 3: LD triangle plots for individual chromosomes of the A and B genomes studied 263 wild emmer accessions produced from 11393 SNP markers.











Supplementary Fig. 4: Manhattan and Q-Q plot of above ground traits in all three environments; Environment 1 (E1) on the left side, Environment 2 (E2) on the middle, and Environment 3 (E3) on the right side.

